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RESPONSES OF PRAWN TO WATER FLOW RATES

Report No 87-105-K

G.L. Vascotto, Senior Research Scientist
and
P.U. Niklas, Lead Technician
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ABSTRACT

An aquarium study to determine the responses of postlarval Macrobrachium rosenbergii to varying water changes was carried out. Six week old postlarvae were raised in glass aquaria receiving 0, 1.15, 7.2, and 14.4 water changes per day over a 12 week period. The treatments had significant influences on survival, biomass, and average size of the animals. Maximum survival and highest biomass were found in the 1.15 water turnover treatment; however, this treatment also produced the smallest average size animals. Early high mortalities were attributed to poor growing conditions in the high and low flow treatments, while later mortality appeared to be biomass dependent.

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34-557-011	836.4	May 28, 1987	87-105-K

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EXECUTIVE SUMMARY

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As part of the thermal aquaculture investigations a series of small scale studies are being carried out to determine the parameters that would allow the raising of prawn at Southern Ontario latitudes. Existing commercial ventures use extensive growth techniques and all use shallow ponds with standing water. Since our schemes for thermal aquaculture are based on intensive growth techniques, and most likely under flow through conditions, an investigation to determine the effect of water flow on survival and growth under laboratory conditions was carried out and is here reported.

In the study, twenty six-week old prawn postlarvae were raised in glass aquaria receiving 0, 1.15, 7.2, and 14.4 water changes per day over a 12 week period. The treatments had significant influences on survival, biomass, and average size of the animals. Maximum survival and highest biomass were found in the 1.15 water turnover treatment; however, this treatment also produced the smallest average size animals. The no flow aquaria, in spite of extensive aeration, lost a high proportion of the animals in the first four weeks, as did the high flow treatment. The early losses were attributed to poor growing conditions in the high and low flow treatments, while later mortalities appeared to be associated with the biomass present at the previous weighing and on the presence of very large individuals. Since mortality increased in all aquaria having biomass greater than 25 gm, it was speculated that water borne metabolites produced by the animals or food quality may have caused the higher mortality.

Literature reports indicated that in the commercial ponds, which have no or minimal flow through or water purification, oxygen was the main limiting factor for survival, but in our studies other factors are implicated, and water purification may be necessary. Also, the ability to create an artificial pond environment, complete with interacting members of a detritus based food web may be critical to the success of intensive prawn aquaculture.

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TO: Dr. D. Mills
Director of Research

RESPONSES OF PRAWN TO WATER FLOW RATES

INTRODUCTION

Ontario Hydro Research has, over the last two years, carried out a series of investigations to assess the feasibility of developing a warm water aquaculture industry based on the commercial raising of Malaysian prawns (Macrobrachium rosenbergii) using thermal effluents. The prawns are commercially grown in several tropical countries using extensive techniques. The animals grow rapidly in fresh water, can grow to substantial size (500 gm animals are not uncommon in Indonesian markets [Malecha 1980]). However, the animal is not yet domesticated, and problems with the production of high yields, and production of large numbers of animals of marketable size exist.

Early experiments designed to gain experience in growing Malaysian prawns by the Biological Research Section yielded disappointing results in terms of survival (Ontario Hydro Research Division Report No 84-458-K). Subsequent studies conducted in concrete pools and cages resulted in considerably better growth and survival which was attributed to a more complete diet (Ontario Hydro Research Division Report No 85-192-K). However, the investigators also noted that in the latter studies the waters were not as clean as in earlier studies and speculated that enriched waters may enhance survival were made.

Commercial culture practices consist of raising the animals in shallow, open, earthen ponds. These ponds often become anoxic and artificial aeration has to be provided (D. Stechey personal communication). The animals are usually fed a commercial pelletized feed, chicken broiler starter being a common feed (Malecha 1980). Considerable research on optimizing the food ration is currently being undertaken in Hawaii. The role played by the feed has been questioned, and speculations that its primary role may be to fertilize the ponds have been made (Malecha 1980, Cohen et al 1986). In our laboratories it was found that a mixture of commercial prawn feed and ground fish flesh yielded the best growth and survival (Ontario Hydro Research Division Report No 85-192-K).

Since commercial operations are pond based, the rate of water turnover required or its impact on growth and survival has not received attention

in the published literature. Water exchange, however, play an important role in intensive aquaculture schemes. The objective of this study was to determine the importance of water residency on growth and survival of the animals. The assumption made was that low water turnover would create a fertile growing environment with an accumulation of organic detritus and possibly metabolites; while higher water turnover rates would result in 'cleaner' environments having low accumulations of detritus and metabolites.

METHODS

The study was carried out in the laboratory. The experimental units consisted of 12 glass aquaria (99 cmL, 43 cmW, 46 cmH), partially submerged in six 1.2 m diameter fiberglass tanks. Each tank held two aquaria which were randomly allocated. The temperature in the aquaria was maintained between 27°C and 30°C by a flow thru system. Temperature control in the aquaria was primarily achieved by submersing them in the tanks which acted as water baths coupled with the addition of the warm water into individual aquaria to obtain the desired flow rates.

The experiment consisted of four treatments with three replicated aquaria per treatment. The treatments were no water flow (half of the water was replaced once a week), low water flow (1.15 water changes per day), medium water flow (7.2 water changes per day), and high water flow (14.4 water changes per day). The no flow aquaria were aerated to ensure an adequate oxygen supply. Each aquarium was provided with eight strips of corrugated PVC set on the bottom for additional surface area (see Ontario Hydro Research Division Report No 86-267-K for description of the strips). Each aquarium was covered with fiberglass screening to prevent the animals from jumping out.

The animals were obtained from Amorient Farms in Hawaii. Six week old postlarvae between 0.15 and 0.30 gm blotted weight were used for the experiment. Twenty randomly selected animals were allocated to each replicate. Food was provided on a daily basis, and consisted of Rangen Prawn Food pellets (40% protein). Each ration was estimated at five percent of the aquarium biomass. The animals in each aquarium were blotted, weighed and counted at four week intervals. The experiment lasted 12 weeks.

The following water quality parameters were monitored weekly starting at the end of the first week: oxygen concentration, pH, and conductivity, while temperature was measured daily. The underlying assumption of the experiment was that water flow influenced the amount of food detritus both in suspension and being broken down on the bottom of the aquaria. As an indicator of detritus in suspension, turbidity and total suspended solids were measured at weekly intervals. As an indicator of organic detritus on the aquaria bottom at the end of the experiment the material accumulated was collected and the dry weight following drying to constant weight was determined.

Following the weighing of the animals at the end of the eighth week one of the low flow replicates was lost thus resulting in unequal replicates for the final month.

The survival data were analyzed using the ANOVA for Balanced Designs for 0, 4 and 8 weeks, and ANOVA for Unbalanced Designs for the final weighing. The procedure in Statgraphics, by Statistical Graphics Corporation, was used. The biomass data were analyzed using the ANOVA with unequal subsample numbers using the GLM procedure in SAS/STAT for personal computers.

RESULTS

Water Parameters

The temperature variations in the aquaria during the 12 weeks were generally less than 1.5°C. The temperatures never rose above 31.6° or dropped below 27.6°C. Since temperatures were maintained by a combination of warm flow and water bath, some variation in temperature among treatments was evident. The high flow treatment was consistently the warmest, averaging 30°C or 0.3°C higher than the medium flow treatment. The low flow treatment averaged 29°C, or 1.0°C colder than the high flow treatment. The no flow treatment was the coolest by 0.4°C. The temperatures were all within acceptable growing conditions and would not be expected to influence survival.

The water chemistry parameters are summarized in Table 1. As shown by the standard deviations the variability among replicates was small indicating consistent control.

At the start, oxygen levels were similar in all treatments, ranging from 5.5 to 5.9 mg/L. Oxygen was maintained close to saturation in all aquaria except for the low flow treatment where it dropped from an average of 5.5 mg/L or 80% saturation during the first week to a low of 3.1 mg/L or 40% saturation during the ninth week. This latter dissolved oxygen level is not considered limiting in prawn aquaculture (Arieli et al 1981).

pH was also similar in all treatments at the start, ranging 7.7 to 8.0, the latter value occurring in the no flow treatment. pH did not change appreciably in three of the treatments but rose to 8.4 in the no flow.

Conductivity was similar at the start (approximately 280 umho/cm) in all but the low flow treatments, and increased slightly (less than 5%) over the 12 week period. In the no flow treatment conductivity was 10% higher than the other treatments at the end of the first week, and increased by 23% ending at 344 umho/cm at three months. Recent water tests in other experiments suggest that the elevated conductivity is due to accumulation of ammonia, which was not monitored in this experiment.

Levels of total suspended solids were inversely proportional to the water flow in the aquaria, being lowest in the high flow treatment. Turbidity followed a similar pattern as total suspended solids.

Treatment	Variable	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	Pre Average
N.F.	Conductivity	389.7	336.7	336.7	242	241	241.3	240	240.3	241.3	270.3	261.7	256	246.17
	mho/cm	0.9	2.5	1.7	2.2	5.4	11.4	4.2	5.2	5.3	5.3	4.9	8.6	4.91
L.F.	"	194	191.3	193	190	191.3	192.7	190	196.3	196.7	196	191	190.7	193.00
	"	0.8	2.9	0	1.4	1.2	5.5	1.4	0.5	0.9	1.6	1.6	0.9	1.01
M.F.	"	190.7	189.3	191.3	191.7	190	195.3	194.7	191.7	193	191.7	190.7	196	189.19
	"	0.5	0.9	0.9	0.5	0	0.5	0.9	0.5	0.5	0.5	1.4	1.6	0.03
H.F.	"	179.7	188.3	191.3	191.3	195.7	195.7	192.7	191.3	191	191.7	196.3	194.3	188.69
	"	0.5	0.5	0.9	0.5	1.3	0.5	0.9	0.5	0.5	0.9	1.3	1.3	0.99
N.F.	Diss. Oxygen	5.9	6.3	7.3	6	6.3	5.9	7.4	6.6	6.6	6	6.4	6.7	6.18
	mg/L	0.1	0.6	0.1	0.4	0.5	0.3	0.5	0.1	0.3	0.1	0.1	0.3	0.59
L.F.	"	6.6	6.3	6.7	6.3	3.9	6	6.1	3.7	3.1	3.4	3.9	6.4	6.19
	"	0.3	0.9	0.3	0.4	0.6	0.9	0.4	0.4	0.7	1.1	1	1.3	0.64
M.F.	"	6.7	6.3	6.7	6.1	6.1	5.9	8	6.1	6	6.9	6.9	6.4	6.33
	"	0.3	0.7	0.3	0.4	0.3	0.3	0	0.9	0.3	0.4	0.1	0.4	0.34
H.F	"	6.6	6.6	6.7	6.6	6.6	6.6	6.4	6	6.6	6.6	6.6	6.7	6.69
	"	0.3	0.4	0.1	0.3	0.1	0.1	0.5	0.4	0.1	0.3	0.3	0.6	0.33
N.F.	pH	0	7.9	8.3	8.1	8.1	8.3	8.3	8.3	8.3	8.3	8.4	8.4	8.11
		0.3	0.1	0	0.1	0.1	0	0.1	0	0.1	0.1	0.1	0	0.09
L.F.	"	7.7	7.7	7.7	7.7	7.6	7.7	7.6	7.6	7.6	7.6	7.7	7.8	7.67
		0	0	0	0.1	0.1	0	0	0.1	0	0.1	0.1	0	0.04
M.F.	"	7.7	7.7	7.8	7.7	7.7	7.7	7.9	7.8	7.8	7.8	7.8	8	7.79
		0.1	0	0	0	0	0	0	0	0.1	0	0.1	0	0.03
H.F.	"	7.7	7.8	7.8	7.7	7.8	7.8	8	7.8	7.9	7.9	8.1	8.1	7.87
		0.1	0.1	0	0	0	0	0	0	0.1	0	0.1	0.1	0.04
N.F.	Tot.Sus.Sol.	0.0003	0.0016	0.0018	0.0013	0.0003	0.0009	0.001	0.0018	0.001	0.0015	0.0019	0.0015	0.0013
	mg/L	0.0001	0.0003	0.0001	0.0007	0.0001	0.0003	0.0006	0.0009	0.0006	0.0016	0.0014	0.0017	0.0009
L.F.	"	0	0.0008	0.0006	0.0003	0.0006	0.0011	0.0017	0.0006	0.0009	0.0009	0.0011	0.0013	0.0009
	"	0	0.0011	0.0003	0.0002	0.0001	0.0003	0.0003	0.0006	0.0001	0.0003	0.0008	0.0006	0.0004
M.F.	"	0.0003	0	0.0003	0	0.0001	0.0003	0.0007	0.0001	0.0003	0.0007	0.0013	0.0015	0.0003
	"	0.0004	0	0.0004	0	0.0002	0.0003	0.0001	0.0001	0.0003	0.0001	0.0006	0.0006	0.0003
H.F.	"	0.0001	0.0001	0	0	0.0001	0.0001	0.0004	0	0	0.0003	0.0001	0.0009	0.0001
	"	0.0001	0.0001	0	0	0.0001	0.0001	0.0001	0	0.0001	0.0001	0.0003	0.0004	0.0001
N.F.	Turbidity	1.55	0.93	1.07	1.07	0.74	0.71	0.78	0.9	1.17	1.07	1.33	1.09	1.17
	JTU	1.11	0.09	0.19	0.13	0.2	0.11	0.16	0.13	0.17	1.27	0.52	0.19	0.19
L.F.	"	0.63	0.61	0.6	0.61	0.66	0.61	0.68	0.68	0.77	0.74	0.63	0.61	0.67
	"	0.01	0.03	0.04	0.14	0.11	0.1	0.09	0.05	0.04	0.13	0.08	0.1	0.08
M.F.	"	1.16	0.66	0.68	0.64	0.6	0.68	0.81	0.81	0.81	0.66	0.64	0.67	0.63
	"	0.08	0.04	0.3	0.08	0.05	0	0.14	0.01	0.01	0.01	0.1	0.04	0.14
H.F.	"	0.66	0.6	0.61	0.67	0.66	0.68	0.69	0.64	0.67	0.68	0.66	0.66	0.68
	"	0.14	0.04	0.05	0.05	0.03	0.01	0.01	0.01	0.01	0.06	0.05	0.01	0.05
N.F.	Temperature	17.8	17.77	18.1	19.67	18.67	18.77	18.9	18.67	18.67	18.1	17.77	17.8	18.38
	Degrees C.	0	0.11	0	0.11	0.05	0.05	0.14	0.11	0.17	0.16	0.38	0.26	0.14
L.F.	"	19.8	18.33	18.1	19.83	19.67	19.33	19.8	19.67	18.8	19.67	18.77	18.73	18.98
	"	0	0.24	0	0.24	0.15	0.48	0.16	0.19	0.08	0.25	0.61	0.38	0.22
M.F.	"	19.6	19.1	18.1	21.83	19.6	18.13	18.17	19.83	19.67	19.6	19.67	19.87	19.78
	"	0	0.16	0	0.89	0.14	0.12	0.24	0.31	0.17	0.29	0.31	0.09	0.17
H.F.	"	19.9	19.4	18.1	21.6	20	18.53	18.67	18.67	18.13	19.77	19.6	19.97	19.08
	"	0	0.08	0	0.16	0.16	0.05	0.11	0.09	0.19	0.17	0.36	0.09	0.11

Table 1. Mean and Standard deviations of weekly values of chemical determinations in each treatment.
(Treatments: N.F.= No flow, L.F. = Low flow, M.F. = Medium flow, and H.F. = High flow)

TABLE 1

SUMMARY OF WATER CHEMISTRY PARAMETERS

Survival

The aquaria were stocked at a density equivalent to 80 animals per m^2 of bottom, substantially higher densities than those found in commercial situations. The animals were overstocked to find where density would level off, and whether this level varied with treatment.

The survival data are summarized in Figure 1. For each month there were significant differences in survivorship among treatments (Table 2).

TABLE 2

TREATMENTS

TIME	NO FLOW	LOW FLOW	MEDIUM FLOW	HIGH FLOW	RESULTS of ANOVA
WEEK 0	20 (0)	20 (0)	20 (0)	20 (0)	
WEEK 4	4.0 (2.2) B	16.3 (0.9) A	15.3 (0.5) A	8.7 (1.7) C	(P=.0001,F=31.3,df 3,8)
WEEK 8	2.7 (1.2) B	1.3 (0.5) A	11.3 (2.6) A	2.3 (0.9) B	(P=.0003,F=21.8,df 3,8)
WEEK 12	2.0 (0.8) B	9.0 (0) A	4.0 (2.2) B	1.7 (0.5) B	(P=.005, F=10.9,df 3,7)

The mean number of animals per aquaria surviving at the end of each four week period. Standard deviations are shown in brackets. The groupings formed for each four week period by LSD at P=0.95 are identified by the capitalized letters.

During the first four weeks the no flow aquaria lost 80% of the animals, the high flow treatment lost almost 57%, and the low flow and medium flow treatments behaved identically (no difference as determined by LSD) losing approximately 20-25% of the animals in the month. In the following month approximately 33% of the remaining animals in the no flow treatment were lost, 74% of the remaining in the high flow were lost, while the other two treatments lost an additional 25% of the animals. The net results at the end of two months were significant differences in survival between both

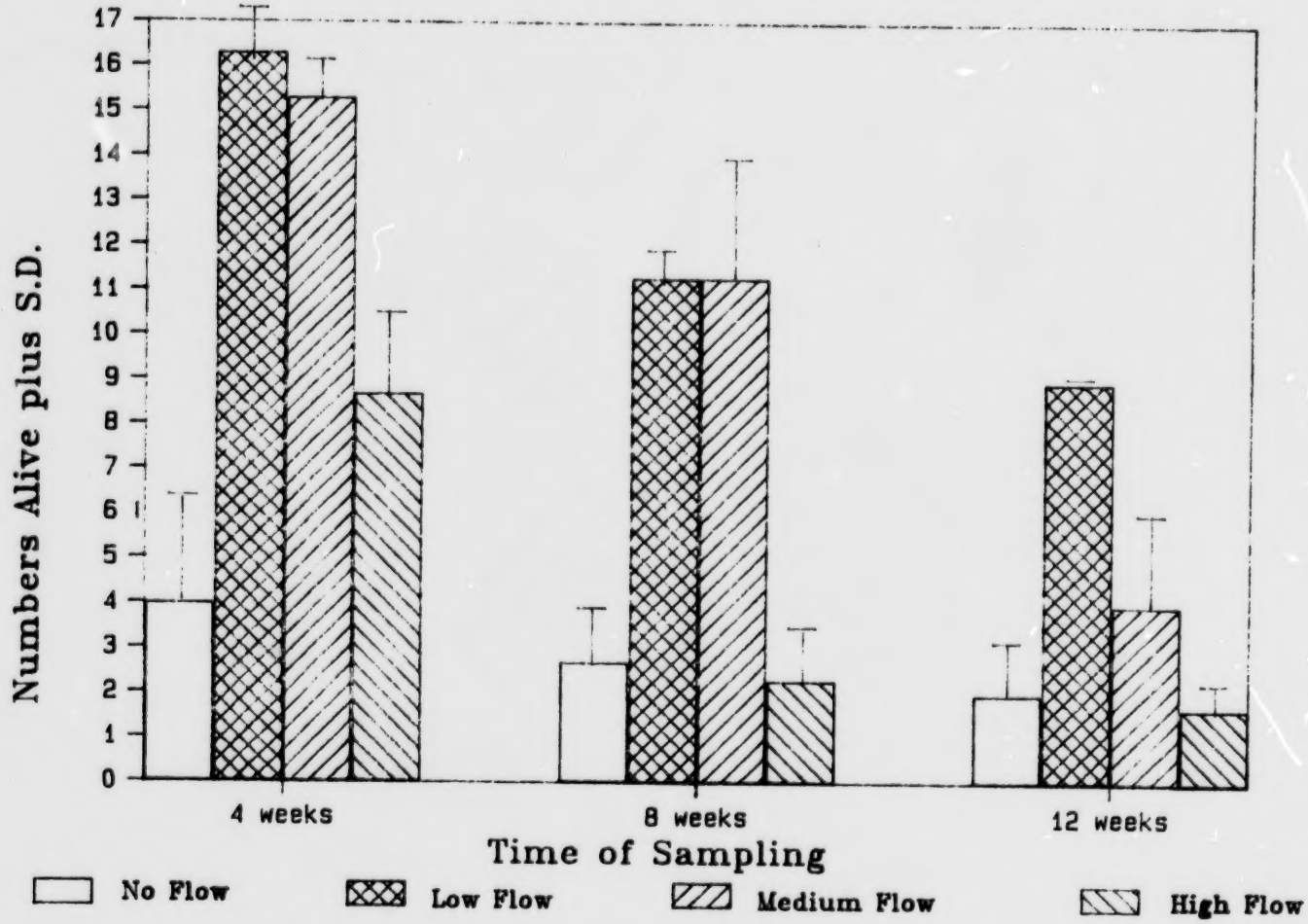


Figure 1. Mean number of prawns plus standard deviation surviving at the end of each four week period.

the low and medium flow treatments and the high and no flow treatments. In the final four weeks the low flow treatment again lost approximately 20% of its numbers while the medium flow treatment lost over 60% of the prawns. At the end of the experiment there was no significant difference in survivorship between the no flow, medium flow, and high flow treatments, while there was a significantly higher (3X) survival in the low flow treatment.

Relative mortality rates were significantly different during the first four weeks between the high and no flow and the low and medium flow treatments. At the end of the second and third four week periods only the low flow treatment was different, exhibiting significantly lower mortality rates.

Biomass

The initial biomass in the aquaria ranged from 3.56 gm to 4.3 gm. At the end of the first four weeks the weights ranged from 2.81 gm to 18.55 gm, at the end of the second four weeks the biomass ranged from 4.22 to 39.52 gm, and by the end of the study the values ranged from 5.82 to 30.15 gm (excluding the damaged replicate).

For each of the three sampling periods there was a significant difference in biomass present in the treatments, with the low flow and medium flow treatments having significantly higher biomass than the no flow and high flow treatment (Table 3).

In the no flow and high flow treatments there was approximately a doubling of biomass during the study, but considerable variation among replicates existed, particularly at the end of the first four weeks as evidenced by the standard deviations (Table 3). The low flow and medium flow treatments were characterized by a more than a 300% increase in biomass during the first four weeks, a greater than 50% increase in the second four weeks, and no change in the low flow during the third four weeks, but an average decline in the medium flow (Table 3). It is evident from the biomass changes shown in Figure 2 that the segregation between "good" and "poor" growing conditions become apparent during the first four weeks, becoming more pronounced in the second four weeks. In the last four weeks, however, all the replicates which entered the period with a biomass of over 25 gm lost biomass (Figure 2a), while the two replicates which entered the period with a biomass of between 20 and 23 gm continued growing and ended at 22.85 and 30.15 gm respectively (Figure 2b).

At the termination of the experiment the medium and low flow treatments yielded a biomass of approximately 25 gm per aquaria, which was significantly higher than the no flow (10.2 gm/aquaria) and the high flow (7.3 gm/aquaria).

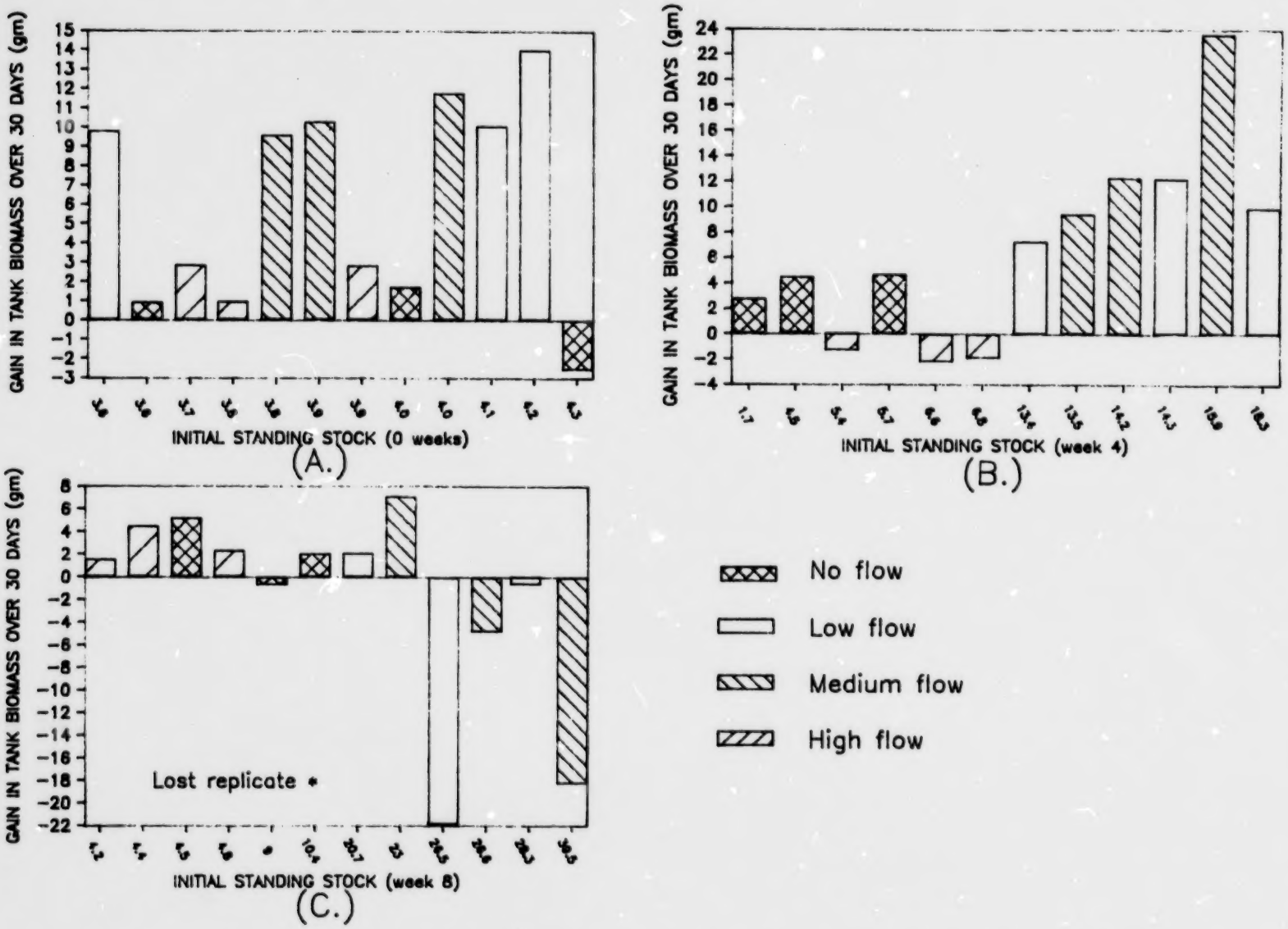


Figure 2. Biomass changes in gm/aquarium between a)0 and 4 weeks b)4 and 8 weeks, and c)8 and 12 weeks.

TABLE 3

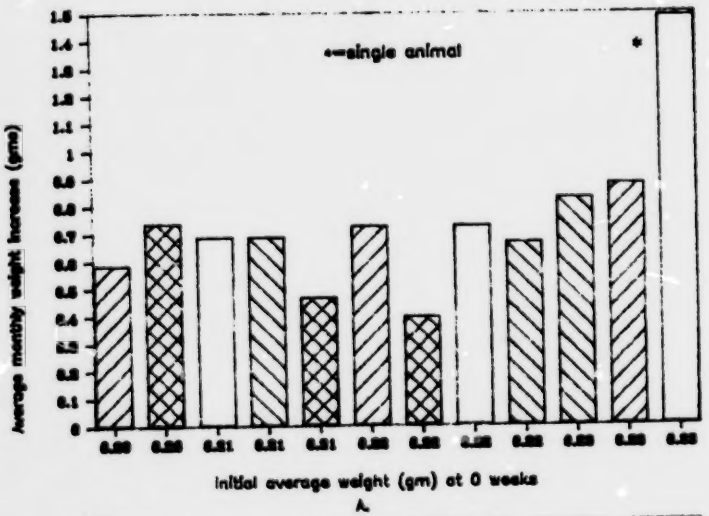
TREATMENTS

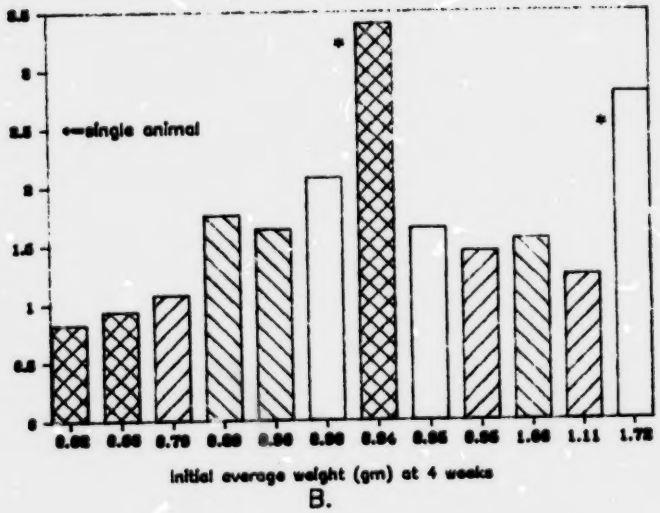
TIME	NO FLOW	LOW FLOW	MEDIUM FLOW	HIGH FLOW	RESULTS of ANOVA
WEEK 0	3.94 (0.08) A	3.97 (0.07) A	3.92 (0.09) A	3.81 (0.08) A	N.S.
WEEK 4	3.98 (1.67) B	15.30 (2.12) A	14.51 (1.00) A	6.26 (0.60) B	(P=.0007,F=21.3,df 3,8)
WEEK 8	7.98 (2.51) B	25.18 (3.24) A	29.69 (7.10) A	4.47 (0.27) B	(P=.0002, F=29.2,df 3,8)
WEEK 12	10.18 (1.78) B	25.55 (2.69) A	24.38 (4.08) A	7.31 (1.26) B	(P=.0006, F=18.5,df 3,7)

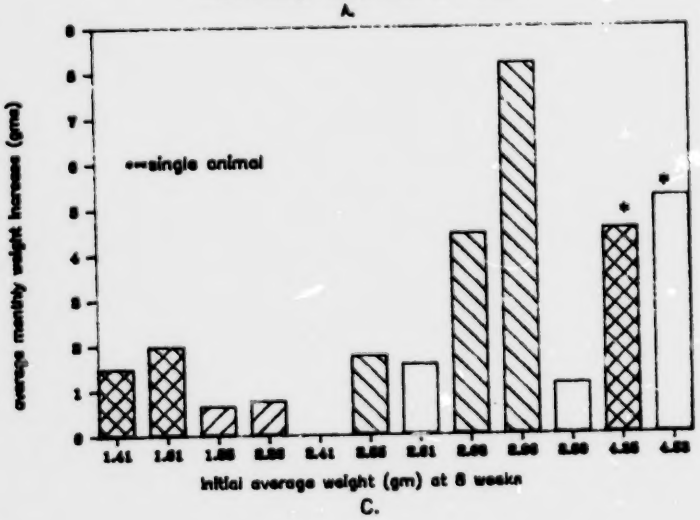
The mean biomass in grams per aquaria at the end of each four week period. Standard deviations are shown in brackets. The groupings formed for each period by LSD at P=0.95 are shown by capitalized letters.

Structure and Growth

By the end of the first four weeks the weight of individual animals within each aquaria varied but the animals in the high flow treatment had a significantly lower average size than the rest (Table 4). Exceptions to the above occurred in both the no flow and high flow treatments where only one animal survived (Figure 3). The variation within replicates increased with age and size. The average weight of the animals did not differ among treatments until the final weighing, when the low flow animals were found to be smaller than either the no flow or the medium flow treatments. At the end of the 12 weeks the low flow treatment was composed of numerous animals of relatively uniform size and having the lowest average weight, 2.79 gm, of the four treatments. The medium flow treatment had the largest animal and the largest average weight animals 6.10 gm, and was also characterized by the largest variations in weights both within replicates and within treatment (Table 4).






average monthly weight increase (gms)
<--single animal
*
*
1.41 1.81 1.88 2.06 2.41 2.85 2.81 3.06 3.06 3.00 4.35 4.53
Initial average weight (gm) at 8 weeks
C.

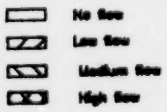


Figure 3. Average weight gain per animal at 4 week intervals. a)4 weeks b)8 weeks, and c)12 weeks.

TABLE 4

TREATMENTS

TIME	NO FLOW	LOW FLOW	MEDIUM FLOW	HIGH FLOW	RESULTS of ANOVA
WEEK 0	0.22 (0.05) ((0.36))	0.22 (0.05) ((0.21))	0.23 (0.04) ((0.40))	0.20 (0.04) ((0.95))	N.S.
WEEK 4	0.99 (0.32) A ((0.19))	0.94 (0.29) A ((-0.55))	0.95 (0.30) A ((0.91))	0.75 (0.14) B ((0.95))	(P=.006,F=4.33,df 3,128)
WEEK 8	2.99 (0.95) ((0.28))	2.22 (0.87) ((1.50))	2.62 (1.25) ((1.33))	1.92 (1.09) ((0.32))	N.S.
WEEK 12	5.09 (2.48) AB ((0.16))	2.79 (0.77) A ((0.70))	6.10 (4.53) A ((1.42))	4.39 (2.68) B ((0))	(P=.0256, F=3.452,df 3,39)

Mean individual animal weight in grams at the end of each four week period. Standard deviations are shown in brackets. The groupings formed for each period by LSD at P=0.95 are shown by letters. The standardized mean coefficients of skewness are shown in double brackets.

One of the major impacts of the treatments was on the gain in average weight of the animals per aquaria or average growth per four week period. During the first two periods the animals in the high flow treatment had the lowest growth while the other treatments had similar growths (Figure 3). By the second four week period the low flow treatments began to display a slower growth rate. During the final period the animals in the low flow treatment continued to display a decline in growth rate and ended with the smallest weight gain.

An attempt had been made at the initial stocking to limit the variance and to have as normal a distribution of weights as feasible. By the second four weeks all treatments displayed a distinct positive skewness, which became more pronounced by the third period (Table 4). The degree of skewness varied among treatments, with the most exaggerated tail occurring in the medium flow treatment, where two animals grew to several times larger (14 and 18 gm) than other animals in the treatment (2 to 6 gm). However, even with the two large animals deleted, the average size of the animals

in the medium flow treatment was still larger than those in the low flow treatment.

Interactions Among Variables

Multiple regression was calculated to assess the relationship between mortality at the end of each four week period and the skewness, the degree of deviation of largest individual from the mean, and the biomass at the beginning of the period in each aquarium. The analysis was run separately for each period. For the first four weeks the multiple regression was not significant.

During the second four weeks mortality and aquarium biomass were negatively correlated ($P>0.95$, $R=-0.94$) as the larger number of survivors continued to grow.

Between the eight and twelfth week the regression equation was significant ($P=0.048$, $R2adj.=0.92$), with both aquarium biomass and the degree of deviation in size of each animal from the mean being significant, $P=0.042$ and $P=0.029$ respectively. Mortality was positively correlated with biomass ($P>0.95$, $R=0.87$), as well as with the presence of large individual animals in the aquaria. Survival declined as the biomass in the aquaria increased.

As reported by Malecha (1977) the populations in the aquaria tended to develop toward a positively skewed weight distribution. It was thought that the presence of large individuals in an aquarium might inhibit the growth of the other animals and/or affect survival. A measure of the presence of large animals was calculated as the difference between the weight of the largest animal in an aquaria and the average weight of the animals in the aquarium divided by the mean. No significant correlation between skewness and biomass or change in biomass over successive sampling periods was found. However, as shown by the multiple regression, the presence of very large animals relative to the mean size of the population in individual aquarium did seem to have a negative effect on the number of animals surviving between the second four weeks and the final four weeks.

DISCUSSION

The question of the influence of flow rates on the prawn's growth and survival has not been previously addressed because commercial production of prawns is done in shallow open ponds, in which water is only added to replace evaporative and seepage losses. However, the issue is likely to be significant if intensive culture options are considered, particularly if temperature is likely to be controlled by means of warm water additions.

The overall survival at the end of the twelve weeks ranged from 5% to 45%. These values are below what would be expected in commercial ventures; in pond situations an average of 85% survival has been reported by Karplus et al (1986), and from their figures it appears that in some ponds values higher than 90% survival were recorded. However, their 12 ponds were stocked at very low densities (1-4 prawns per m^2), and survival in aquaria is not comparable to ponds which consist of essentially complete ecosystems.

In this study altering the flow regimes had a dramatic impact on the survival of the test animals particularly during the first four weeks of the experiment. The responses were not linear, as the two extreme flow regimes both had significantly higher mortalities than the two intermediates. Based on the results of the regression analyses and that variation in animal weights in the initial stocking were well controlled it is probable that the mortalities observed were not caused by differences in the structure of the populations in the aquaria but were environmentally induced. It also appears that different environmental factors were causing the observed mortalities in the no flow than in the high flow aquaria.

The no flow aquaria differed from the rest by having elevated conductivity, total suspended solids, turbidity and generally lower temperatures. The latter were well within acceptable conditions (Shang 1981). For the first four weeks the mortality in the no flow tank was probably associated with accumulation of animal byproducts, as indicated by the high conductivity. In commercial operations, low dissolved oxygen is the variable that is often associated with significant mortalities, and during calm periods growers resort to artificial aeration. In this study ample aeration was provided, therefore either products of the food used or produced by the animals themselves, were responsible for the early mortalities.

The high flow treatment had the lowest total suspended solids and turbidity. The mortality in the high flow aquaria during the first eight weeks appear to be related to a nutritional deficiency as evidenced by the lower growth per individual animal compared to the other treatments (Table 4). The animals are known to feed on detrital material. Schroeder et al (1986) showed that for Macrobrachium raised in ponds the principal food sources converted to prawn flesh were bottom detritus, zooplankton, and benthos. The prawn flesh showed very little direct conversion from the pelletized food that was provided. In the type of system used in this experiment the food pellets, following their dissolution into fine particles, were further rapidly broken down, presumably by bacterial action, and created a semi flocculent layer on the bottom of the aquaria. The high flow rates moved any flocculent material rapidly out of the aquaria, keeping the system very clean with the bulk of the material on the aquaria bottom consisting of relatively fresh feed. If prawns depend on the detrital material for food this would have been missing from the fast flow system. This phenomenon may explain some of the lack of success that we have experienced in the past in raising prawns in clean systems. Malecha (1980), considers pond like conditions essential for successful raising of

prawns. Since these animals lack a gastric mill, he builds a convincing argument on the importance of detritus as a prawn food source resulting from the feed being digested by other organisms in the pond system. Malecha stresses that "...'feed' applied to the pond must really be considered an energy input to an ecosystem and not 'feed' in the traditional agricultural sense." These conclusions are supported by Boonyaratpalin and New (1982) who report that natural foods have significant impact on prawn growth rates during the first four months, and describe an incident where "surprisingly good" growth rates were obtained over 110 days by Balazs et al (1976) in fiberglass pools for which no food was added but a luxurious growth of algae existed.

The mortalities that were encountered in the final four weeks seem to be at least partially independent of the flow. The results of the multiple linear regression indicated that the observed mortalities were related to structural characteristics of the population, specifically aquaria biomass exceeding 25 gm, coupled with the presence of large individual animals. These results indicate that while "good" biomass production conditions were present in the second four weeks, the higher biomasses achieved placed a strain on the experimental system resulting in the high mortalities observed in the final four weeks. At this point it is not known what the limiting factor is. Possibilities are limitations imposed by the surface area available, limitations due to the amount of water volume available, or that the ability of the system to cleanse itself of metabolites was exceeded at around the 25 gm of biomass per aquaria. A further limitation may be due to the availability of suitable food and the presence of large and probably aggressive individuals which consume the feed first leaving particles depleted of nutrients for the others as described by Taechanuruk and Stickney (1982). If the latter, or a combination of the above, is the case a balance would have to be struck between good detritus production while maintaining a system with low levels of prawn produced byproducts.

The low flow and medium flow treatments yielded higher biomasses. The highest biomasses and survivals were all encountered in the low flow aquaria; in these the high biomass was a function of high densities of relatively small animals. This type of production would not be desirable in a commercial operation because of the low market value of small animals. Karplus et al (1986), found that higher stocking densities resulted in the production of animals of smaller size, which in turn resulted in a smaller profit. In the medium flow environment the high biomass was due to the presence of few but large animals, with the population having a more positively skewed structure.

CONCLUSION

Any intensive culture option being considered will have to be based on a partial flow through system, as aeration alone is inadequate for growth and survival. It has been shown in this study that water turnover rate has a significant impact on prawn survival and production. The rate of

water turnover should not exceed seven water changes per day. Commercial operations in Hawaii have been described as having a water flow of approximately 75 liters/minute/0.4-hectare growout pond, often for just a few hours per day (Shang 1981), and with good algal growth they appear to be able to maintain good water quality. In our experiment, even at our optimum water turnover rate, unknown factors were limiting the biomass that could be maintained. Work to identify factors which limit biomass production primarily volume, surface area, or water chemistry are being initiated.

If the limiting factor is related to the unavailability of the proper food base, i.e. if the food required is mostly a product of digestion of decomposers, then the ability to create an artificial pond environment, complete with interacting members of a detritus based food will be critical to the success of intensive prawn aquaculture.

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